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AUTOMATED ASSEMBLY IN SPACE

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ABSTRACT

The installation of robots and their use for assembly in space will create an exciting and promising future for the U.S. Space Program. The concept of assembly in space is very complicated and error prone and it is not possible unless the various parts and modules are suitably designed for automation.

This paper develops certain guidelines for part designing and for an easy precision assembly. Major design problems associated with automated assembly are considered and solutions to resolve these problems are evaluated in the guidelines format. Methods for gripping and methods for part feeding are developed with regard to the absence of gravity in space. The guidelines for part orientation, adjustments, compliances and various assembly construction are discussed. Design modifications of various fasteners and fastening methods are also investigated.

In phase 2, a smart menu driven user friendly software will be developed containing all these guidelines and rules. Finally, this software will be implemented and its performance will be evaluated. Some examples will be considered and tested using the guidelines and/or software.

AUTOMATED ASSEMBLY IN SPACE

Introduction

In the coming years, the first permanently manned space station, which will perform such tasks as collection of data from distant stars, repairing satellites and manufacturing of extremely pure pharmacological products, will be launched. The space robots will be designed in such a way that they would assemble the space station itself, perform satellite repairing and testing, and various extra vehicular activities (EVA) under the control commands given from the earth station. Almost total reliance upon space robots in the space station will free astronauts for accomplishing more significant tasks including taking advantage of unforeseen opportunities, solving unexpected problems, occasionally saving a mission, supervising machines and acquiring, integrating and interpreting multisensory data.

The concept of assembly in space seems quite complicated, unproductive and error prone unless various parts and modules are suitably designed for automation from the beginning.

This paper basically focuses on the development of such guidelines and rules for the design of products that will be assembled in space. The parts once designed with these considerations will be easily assembled by simple telerobots, programmed robots or manually, without any error and in shorter time. It will also reduce the need for complicated grippers and end-effectors to monitor the assembly process.

In addition, these proposed modifications that are incorporated into the design of a part facilitate easy handling, omit orientational ambiguities and require simple assembly steps by robots. What is more important about these guidelines is their applicability under the prevailing condition of zero gravity in space.

Development of Guidelines and Rules

1. Design for Part Handling and Gripping

The gripping of the components to be assembled is the most difficult part of assembly by robots in space. If the components are not gripped properly, they can become projected missiles and damage vital equipment as well as the spacecraft and the astronauts. While designing the products and the grippers, care should be taken so that when the components are moved, their movements are secure, verifiable and failsafe.

For higher productivity in assembly by robots in space, the design of the general purpose gripper is a critical factor. The design emphasis and functional requirement of grippers used in industries and space are different in some respects. The object escaped from the end-effector would take off with a velocity in an arbitrary direction determined by the robot motion, transforming it into a potentially harmful projectile. The grip provide by the end-effector has necessarily got to be failsafe. This requirement translates into considerations such as positive grasp (see Fig. 1), low friction grasping surfaces, sensory verification, zero back-drivability, and extreme gripper strength. Furthermore, the issue of compliance in space robotic gripping should be considered. Compliance has to be incorporated either in the object, fixture, gripper, or the arm. In the majority of the cases vacuum suction and magnetic pick will be used for part handling (see Fig. 2).

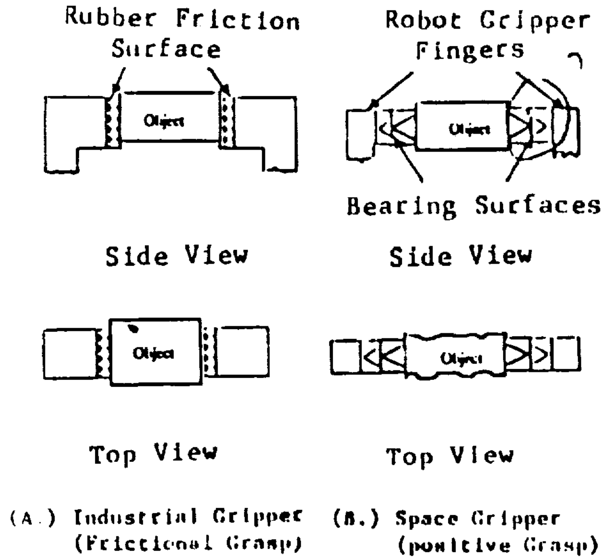

Figure 1

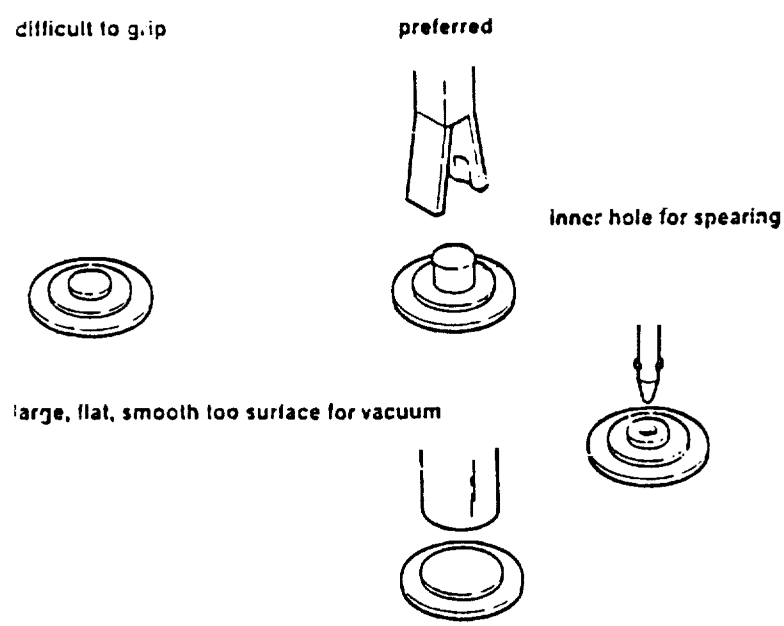

Figure 2

2. Design for Part Feeding and Orientation

There are several key concerns when considering design for proper part feeding and orientating. Parts coming to the assembly station are usually bulk components. They are fed along a suitable conveyor-media (a conveyor box) and will be latched between two fixed ends in the space ship, and thus avoiding the parts swimming in space.

First, part dimensions should be designed to facilitate automation. It is very difficult to automatically orient parts that have dimensions that differ by only a small amount. The obvious alternative is to make these parts' dimensions either identical or their differences more pronounced.

Second, a part should be designed so that symmetry is the priority. It will be a lot easier for a robot to handle a symmetrical part than an asymmetrical part (see Fig. 3). Sometimes asymmetry also makes part orientation easier (see Fig. 4).

Designs should be created so that they do not conflict. This includes avoiding such feeding problems as tangling, nesting, shingling, wedging and jamming. Springs must have closed end loops. Tangling problems are reduced by eliminating protrusions or closing off holes that are unnecessary on the parts (see Fig.5). Parts that travel on a conveyor should be thick enough so that they do not have a tendency to shingle, or start stacking on one another. Additional care should be taken with angles so that the parts do not tend to wedge with each other (Fig.6).

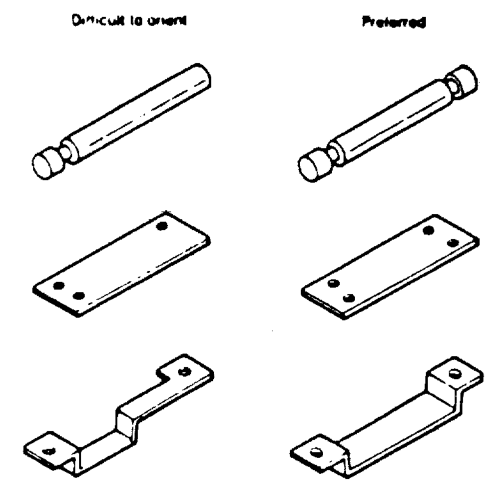

Figure 3

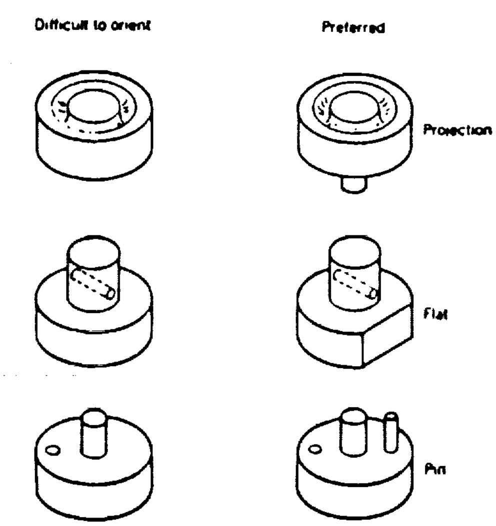

Figure 4

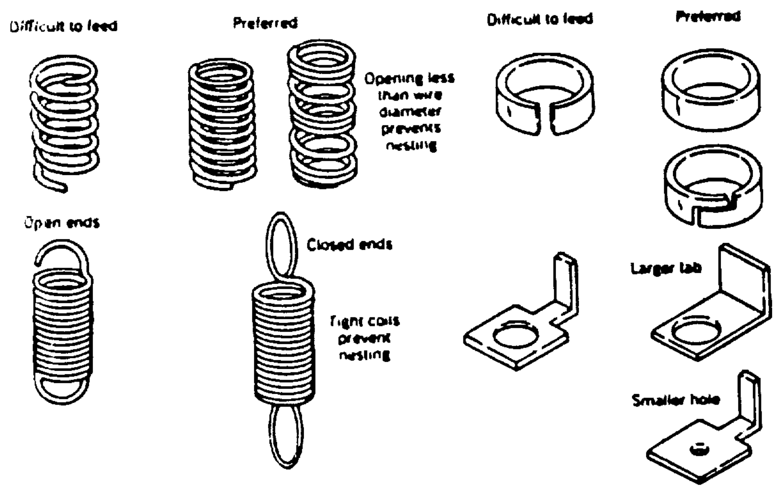

Figure 5

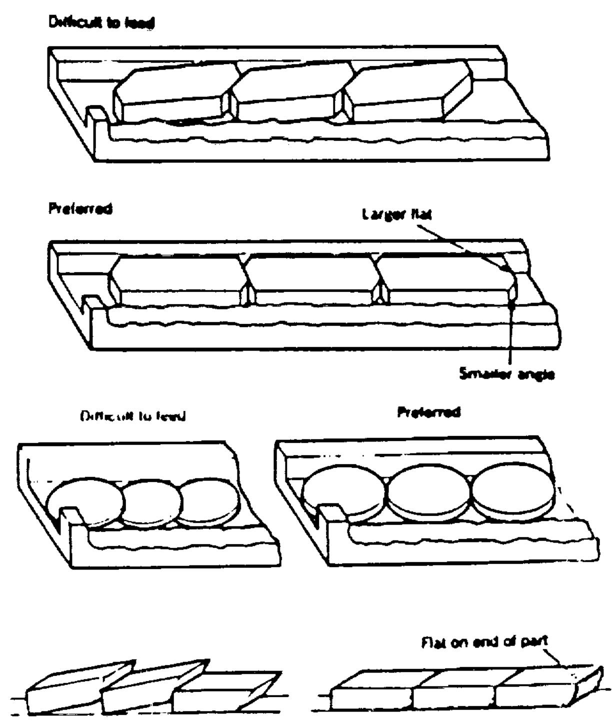

Figure 6

3. Design for Part Fastener

Fastening is one of the most time consuming operations in the assembly. This can be alleviated by using integral fasteners and building the fasteners right into the product, and using snaps and latches built in to fasten parts quickly, without the necessity of extra fastening parts. If screws were to be used in fastening, using the screw with built-in washers, and reducing the screws in number and variety in any component would help. (see Fig.7).

The methods of assembly including mechanical fastening, staging, kiting, and soldering techniques. Devices for feeding and orienting should all be evaluated in order to reduce time of assembly/disassembly.

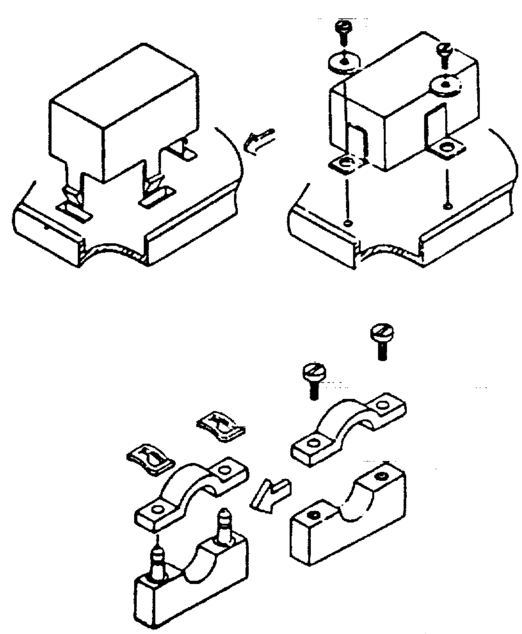

Figure 7

4. Design for Minimum Number of Parts

Economizing on the number of parts either by redesigning or elimination can produce dramatic results for assembly in space. This can only happen if a concentrated effort is made to design equipment which require a minimum number of parts. Fewer parts are advantageous to the assembly cycle, assembly costs, system costs, material costs, and warehousing costs; and in many cases provide a higher quality product (Fig.8).

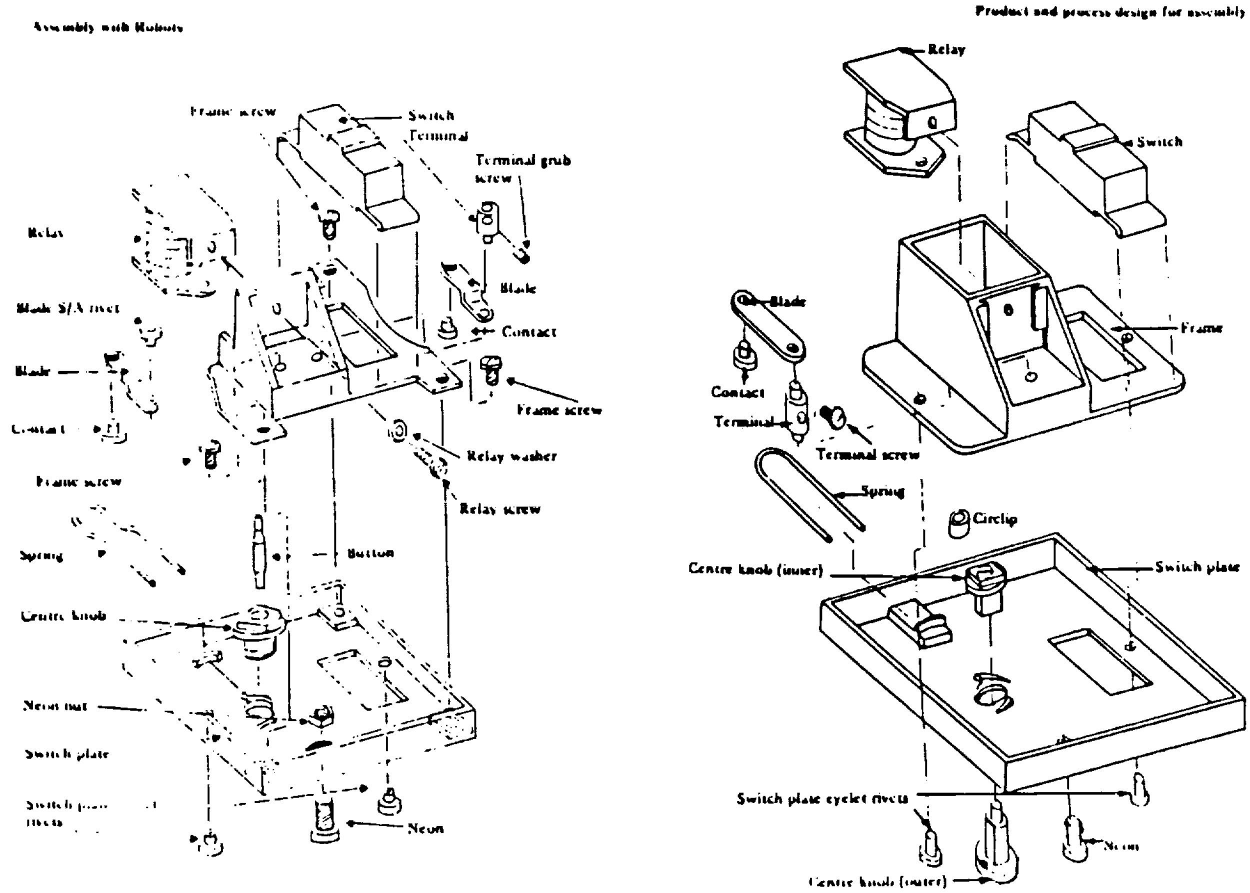

Figure 8

5. Design for Modular Assembly

A strictly structural approach should be taken for assembly of equipment. Designing a product in modules is advantageous. Subassemblies may be built in different areas. Modules may be tested and repaired before final assembly. Model variations can be accomplished at the subsystem level. This system will also make it easier for servicing the part. In addition, assemblies can take place from any direction but must be in optimal sequence (Fig. 9).

6. Design for Minimum Part Variations

When product variation is low, commonality of parts is high. However, if follow on products maintain a family resemblance, the assembly of the product will be greatly simplified, and cost effectiveness and quality for assembly in space will naturally follow(Fig. 10).

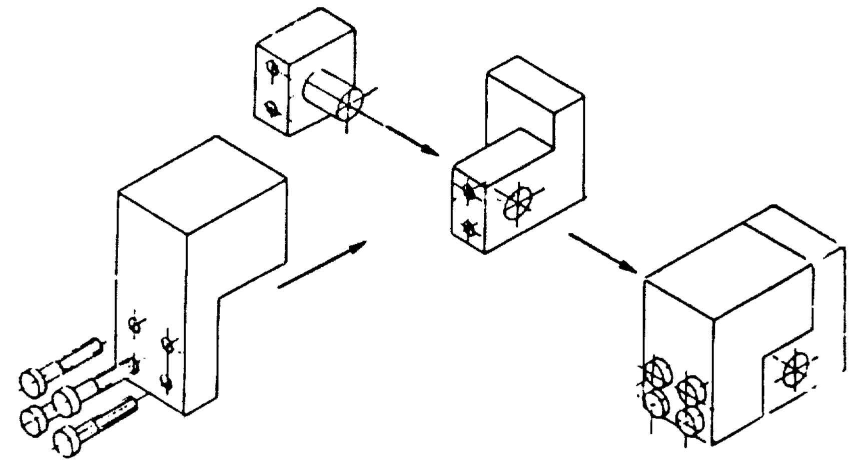

Figure 9

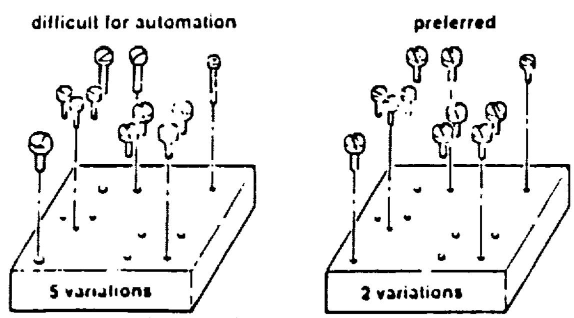

Figure 10

Benefits of Guidelines and Rules

The direct benefits of the space assembly products include: Facilitating automatic assembly with ease, reduction or elimination of the need for expensive electronics normally required for precise positioning, allowing relaxed positioning tolerance, reduction in downtime of assembly equipment by reducing wedging, jamming and damaging of parts, increased productivity with humans functioning as managers rather than as operators, increased responsiveness to innovation since the automated station will become more flexible and adaptable, lower cost of operations with highly automated systems which will run at peak efficiency, uniform quality control, greater autonomy with machine intelligence to support monitoring and control of station systems, thereby lessening reliance on ground support, improved reliability, the ability to perform with robots and teleoperators tasks which are unsuitable to humans alone, for instance, the assembly of large structures, and a reduced need to expose humans to hazardous conditions existing in space.

Conclusion

In conclusion, it can be said that assembly by robots in space will be a very interesting research area. It will help in establishment of a station in outer space to assemble and launch satellites and spacecraft automatically. The space station will also be capable of testing, servicing, refueling and recovering a space shuttle or satellite by teleoperation from the ground. Automated assembly in space stations can also be used for various material processing and manufacturing. The key feature of manufacturing in space is the extended period of weightlessness that is permitted in its low gravity environment. Thus, these guidelines will be helpful in automizing the tasks of the space industry by properly designing various containers, etc., suitable for robotic handling.

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